Evaluation of Impact of Climate Changes on Crop Production and Irrigation Management in the Lower Seyhan Irrigation Project

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1. Introduction

This paper will provide results of an assessment of impact of global warming on irrigation management and agricultural productivity in the Lower Seyhan Irrigation Project (LSIP), the eastern Mediterranean coast of Turkey, with IMPAM (Irrigation Management Performance Assessment Model) that the authors developed (Hoshikawa et al., 2005). IMPAM is a quasi-3dimensional hydrological model to simulate water movement (water balance) and crop productivity in irrigated area.

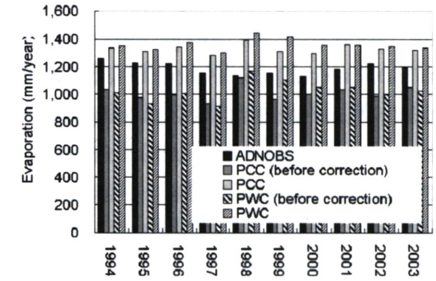
According to simulation results by major global circulation models (GCM), precipitation and river runoff in the Mediterranean region will be decreasing under global warming. They would strongly affect irrigated agriculture that is important for food production in arid/semi-arid regions. Projection of future agricultural productivity and water balance of an irrigated area with simulation models may provide useful information to discuss where is weak to global warming and how the present irrigation system should be improved.

2. Climate data for simulations

All climate data used in this study was calculated by Kimura (2005) from NCEP (National Center for Environmental Prediction) reanalysis data during 1994 – 2003. Climate data in 2070s was derived through a downscaling method called "pseudo warming" where NCEP reanalysis data with climate change trend were downscaled. Present climate data is derived through downscaling of the original NCEP reanalysis data.

Because of some errors and simplifications in the downscaling, solar radiation and temperature were underestimated. Dr. Tanaka (Desert Prevention Research Institute, Kyoto University) made some statistical correction on the downscaled climate data. Amount of evaporation and transpiration that are important factors in water balance of irrigated districts became more reasonable after Dr. Tanaka's correction (**Figure 1**).

For the assessment of global warming in this study, the data corrected by Dr. Tanaka was used (PCC and PWC).



ADNOBS: observed, PCC: present climate calculated, PWC: pseudo warming climate

Fig. 1 Potential soil surface evaporation

3. Model for simulation

Water balance in an irrigated area depends on irrigation and crop management, physical structure of facilities, and spatial structure (topography and facility arrangement) of the area. In addition, spatial dispersion of water balance components such as evaporation, transpiration and groundwater is very large (Figure 8). These facts suggest that results of water balance assessment with 1-dimensional models may provide unreasonable information to assess irrigation management and impacts of environmental changes at tertiary and upper levels, and for simulations of water balance of irrigated areas, it is necessary to take both management and spatial information into the model.

IMPAM that is a distributed model and include simulation modules for management should be fit for the aims of this study. In the following paragraphs, impacts of global warming to the command area of YS7-1-1 will be discussed based on area average values of simulation result by IMPAM.

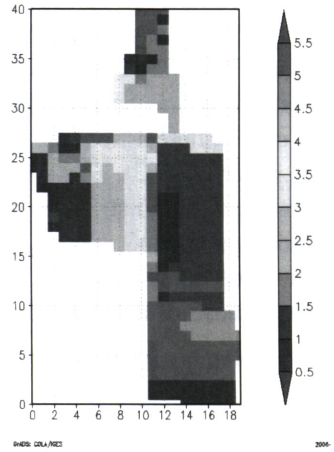


Fig. 2 Example of simulation results by IMPAM

4. Area applied and simulation scenarios

IMPAM was applied to a command area of a tertiary canal YS7-1-1 (**Figure 3, 4**) that belongs to Gazi Water Users Association at the middle of Seyhan Delta, on the left bank of the LSIP. There are twenty plots in the area of about 90 ha, and maize, citrus, vegetable and seedling are cultivated. For the simulations this area was dispersed into 50m x 50m grid (**Figure 4**).

Schedule and amount of irrigation (**Table 1**), amount of seepage loss from irrigation canals, and cropping pattern for the simulations were assumed based on field observations and measurements by Nagano (2005).

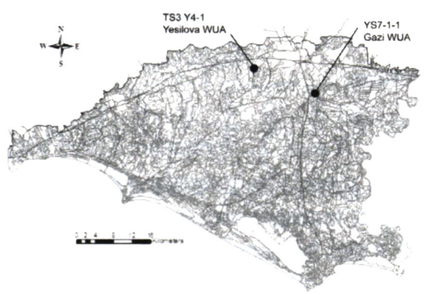


Figure 3 Situation of selected tertiary canals in the LSIP.

Table 1: Annual amount of irrigation for each crop

Crop	Irrigation [mm/year]
Maize	680
Vegetable	300
Watermelon	310
Citrus	770
Seedling	530

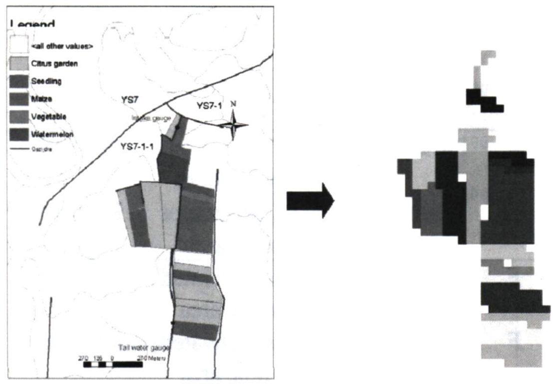


Figure 4 Agricultural plots in the applied area and its dispersion

So far as hydrological environment, global warming will affect irrigated agriculture through climate changes at farm level, at irrigated area level, and at basin level. According to simulation results by major global circulation models (GCM), precipitation and river runoff in the Mediterranean Region including the Seyhan River Basin will decrease under warmer climate in the future. Climate changes in the Lower Seyhan may affect crop growth and water balance, and decrease of runoff may force decrease of water withdrawal from the Seyhan River. Hence two warming scenarios were assumed in this study: first, irrigation amount will not be changed, and second, irrigation amount at farm-level will be decreased by 20% because of decrease of withdrawal from the river. In addition, effect of decreasing irrigation amount by 20% under the present climate is examined for comparison.

To discuss effect of global warming in compared with such socio-economic impacts, simulations under two scenarios: only maize is cultivated both the present and warmer climates, also done. Actually, cotton that was the main crop in the LSIP before was replaced by maize almost completely after 1980s because of economical reasons. Such change in crop would occur in the future again and may affect water balance more strongly than global warming.

It means that simulations will be with the one present and five supposed scenarios (**Table 2**). In the both scenarios C and D, amount of irrigation is decreased by 20% from (80% of) the present amount shown in **Table 1**.

Simulations were done for ten years. The period 1994 – 2003 and 2070s were selected for the present and future scenarios respectively.

Table 2 Six scenarios for the simulations

	Climate	Management	Code
A	Present	Present irrigation amount	PCC
B	Warmer	Present irrigation amount	PWC
C	Present	80% of the present irrigation amount	PCCir08
D	Warmer	80% of the present irrigation amount	PWCir08
E	Present	Maize is cultivated in the whole area	PCCmz
F	Warmer	Maize is cultivated in the whole area	PWCmz

5. Simulation results

5.1 Impact of climate changes

Although potential evaporation in 2070s (under PWC) was larger than that in 1990s (under PCC) (**Figure 1**), actual transpiration and evaporation in 2070s was less than those in the present (**Figure 4**) because of soil drying by decrease of precipitation. Actual transpiration was less than potential when a plant has any water stress, and therefore ratio of actual transpiration to potential transpiration (Ta/Tp) could indicate degree of water stress (no stress when Ta/Tp is equal to 1.0). Crops in 2070s were more water stressed than those in the present (**Figure 5**).

Water stress by soil drying occurred mainly in intervals of irrigation in summer, and sufficient soil moisture was held in root zone in winter even in drought years under the PCC. On the other hand under the PWC, soil moisture in root zone often fell below stress thresholds also in winter as well as in summer, and transpiration of perennial plants (citrus and seedling) in winter was reduced. Water stress had same pattern as a variation of annual precipitation appears in 2070s (**Figures 6**) as a consequence of the water stress in the non-irrigated periods.

This means that agricultural production in the LSIP may become more affected by annual variation of precipitation although it is in the irrigated area.

5.2 Impact of changes in cropping pattern

Most of Gazi area is under citrus garden at the present, and strong impacts of the change into maize mono-culture appeared.

Since there is no crop cultivated except in late spring to early autumn under maize mono-culture, amount of transpiration were much less than under the present cropping pattern. Most of precipitation in winter flowed into drainage channels without being used.

Under maize mono-culture, Ta/Tp-ratio under the warmer climate (PWCmz) was more than that under PCCmz (**Figure 7**) and it is much less dependence on precipitation was seen (**Figure 8**). These situations are quite different from the case of the present cropping pattern (PWC). This should be from the following two reasons: First, maize mainly depends on irrigation water, and second, water logging occurred in some areas with the present precipitation amount because of absence of winter crop.

6. Conclusions

Global warming would affect agricultural production in the LSIP. Under the present irrigation management and cropping pattern, global warming may decrease crop yield and make agricultural production more dependent on precipitation amount.

In addition, change in cropping pattern also would affect crop yield and water balance in the area as well as global warming. And intensity of influence of global warming and its results may vary much with cropping pattern.

7. Acknowledgement

IMPAM was developed in Subject 6 of Research Revolution 2002 (RR2002) "Development of Water Resource Prediction Models", funded by MEXT, Japan

This research was financially supported in part by the JSPS Grant-in-Aid No. 16380164

8. References

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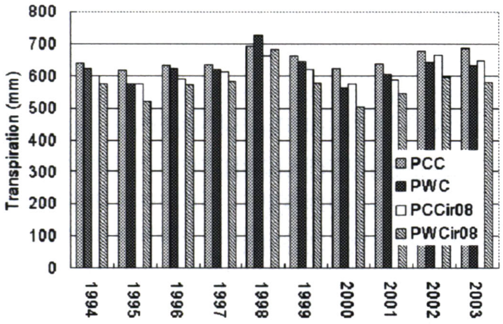
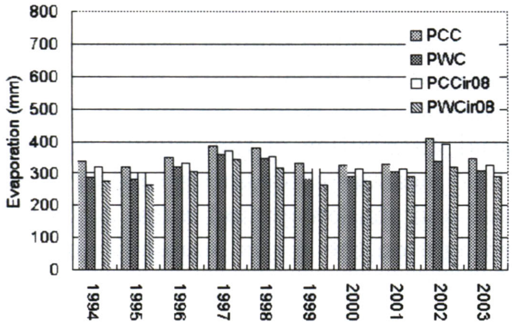
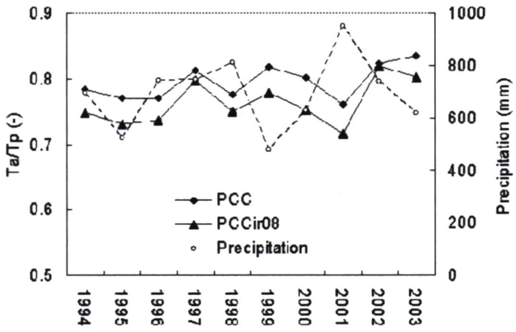


(A) Annual Transpiration

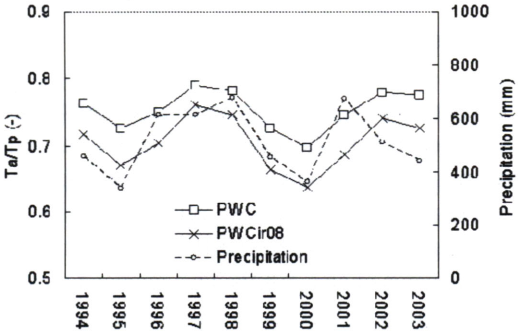


(B) Annual Evaporation

Figure 4 Evaporation and transpiration (present crop pattern)



(A) Present climate



(B) Warmer climate

Figure 6 Ta/Tp-ratio (present crop pattern) and annual precipitation

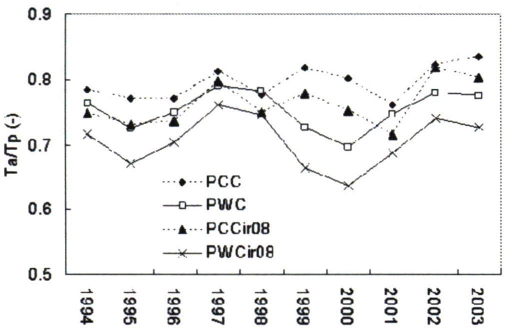
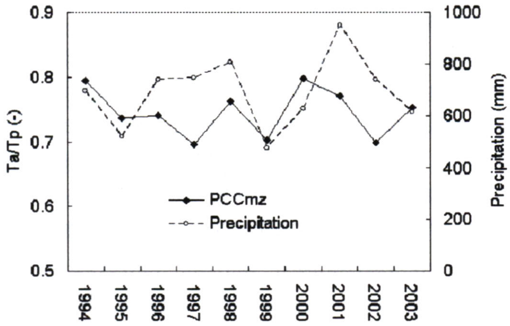


Figure 5 Ta/Tp-ratio (present crop pattern)



(A) Present climate

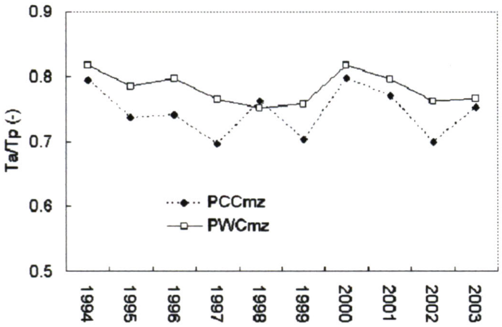
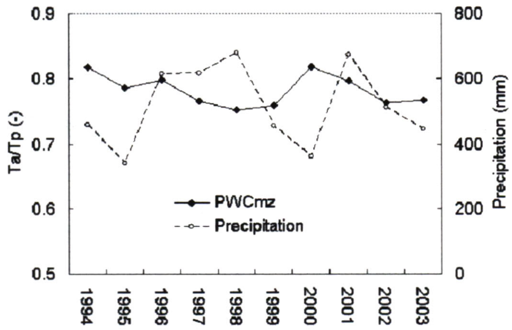


Figure 7 Ta/Tp-ratio (maize mono-culture)



(B) Warmer climate

Figure 8 Ta/Tp-ratio (maize mono-culture) and Precipitation